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ABSTRACT

A study of the manner in which a teacher's arguments can present different messages about authority to learners is discussed. Two analyses of the concept of teaching are examined and the emphasis upon rationality in Western culture is placed in historical context. An analysis of the form of arguments is presented, including an argument-pattern that facilitates the identification of the kind of authority conveyed by an argument. Episodes selected from a set of twelve secondary school science lessons are examined. Analyses of three teachers' arguments illustrate the considerations involved in determining the kind of authority a classroom argument suggests. (MH)

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SE 021 327

TOWARD UNDERSTANDING THE USE OF ARGUMENT AND AUTHORITY IN SCIENCE TEACHING

Thomas L. Russell

Adapted from the author's Ph.D. Qualifying Research Paper,
"Analyzing the Kind of Authority Suggested by Arguments in Science Teaching"
University of Toronto
October 1971

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FOREWORD

The Explanatory Modes Project is a research and development effort in science education sponsored by the Department of Curriculum in The Ontario Institute for Studies in Education. The intent of the project is to further a highly promising but relatively undeveloped area of investigation: philosophical analysis applied to several aspects of science education, including the defensibility of objectives, the characterization of classroom discourse, and the design of teaching materials. The series of Background Papers presents a variety of theoretical considerations and practical applications of systematic information from such areas of scholarly endeavor as philosophy of science, epistemology, and philosophical analysis of teaching. The sample Teaching Materials for secondary school are being designed to illustrate aspects of the nature of knowledge and the processes of explanation, as these are reflected in science especially (but not exclusively).

This paper by Thomas Russell, "Toward Understanding the Use of Argument and Authority in Science Teaching," has been selected as one of the Background Papers because of its potential usefulness to science teachers and teacher educators alike. With increased application to science teaching of a variety of classroom observation schemes has come a gnawing skepticism about the obvious: the power of a scheme for analyzing teaching depends on the purpose of the scheme and the rigor of the conceptualization behind it. Or, in more succinct terms, the most one can hope to "see" in a science lesson is the kind of thing one starts out to look for, and depends on how well one is equipped to look.

The promise of Russell's work in this paper resides partly in the importance of what he chose to look for, in analyzing science teaching. Science teachers, as well as those involved in science teacher education, are well aware of the vague but real discomfort which accompanies the completion of a certain kind of lesson. It goes reasonably well, yet there is the intuitive feeling that the pupils should have been able to perform better, although no clear suggestion for modification of the lesson comes to mind.

Russell's use of Stephen Toulmin's "argument-pattern" as a device for analyzing the conceptual flow and content of a science lesson is extremely helpful for pinpointing potentially useful modifications. It is testimony to the idea that schemes for analyzing science teaching should take into account, at minimum, some rigorous and systematic way to understand the nature of science as a conceptual enterprise.

The commonplace characterization of science as "rational" has, inevitably, become part of the mystique by which science is justified as a subject in general education. Yet as a profession we have at hand few if any means for assessing systematically whether or not science teaching conveys to pupils a message that rational authority is the basis for scientific knowledge. A teacher's socially endowed ("traditional") authority must be used to enforce certain requirements of pupils, especially managerial ones. Accordingly, any science teacher will perforce convey a message that traditional authority is the basis for certain communications in the classroom. It is of great interest to speculate about the possibility that pupils might receive confusing messages about which kind of authority applies to scientific knowledge. By drawing on the work of R. S. Peters, in conjunction with his use of Toulmin's work, Russell has developed an operational way to detect which kind of authority--rational or traditional--is suggested by an episode of science teaching.

Russell's approach in this paper is clear and straightforward. It is demanding for a reader because it is sufficiently complex to match the complexity of events in science teaching. But we only deceive ourselves if we look for simple and undemanding ways to make sense of complex events.

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CHAPTER I

AUTHORITY AND ARGUMENT IN TEACHING

This is a study of the manner in which a teacher's arguments can present different messages about authority to learners. Ideas about the concepts teaching and argument are applied to excerpts from transcriptions of science lessons, in order to illustrate a technique for determining the kind of authority suggested by a teacher's arguments.

In this first chapter, the conceptual background of the study is presented in three parts. First, two analyses of the concept teaching are examined to consider why it is important for teachers to provide pupils with reasons and evidence. Both Komisar and Green have argued that provision of reasons and evidence is implicit in the very meaning of the word "teaching." Second, the importance of reasons, seen as part of an emphasis upon rationality in Western culture, is placed in an historical context. Peters, in comparing rationality and tradition, has expressed the difference in terms of an individual's attitude toward authority. The dual nature of a teacher's authority is considered specifically. Finally, an analysis of the form of arguments is presented. Toulmin has described an argument-pattern which facilitates the identification of the kind of authority conveyed by an argument.

In the second chapter, episodes of science teaching are examined. Analyses of three teachers' arguments illustrate the considerations involved in determining the kind of authority a classroom argument suggests. The third chapter summarizes the results of the analyses of arguments, and relates the results to the concepts presented in the first chapter.

The Importance of Reasons and Evidence

Two recent analyses of the meaning of "teaching" in our culture have stressed the importance of reasons and evidence. In his recent paper titled

"Teaching: Act and Enterprise,"[1] B. Paul Komisar makes an argument for distinguishing three senses of the word "teaching": as occupation, enterprise,[2] and act. Directing his attention to teaching acts, Komisar suggests three categories by which these may be classified: (1) "learning-donor acts" intended to achieve learning, (2) "learner-enhancing acts" intended to establish and maintain a disposition favorable to instruction, and (3) "intellectual acts."[3]

These two sets of distinctions prepare the way for a detailed analysis of "intellectual teaching acts." Komisar argues that the intention of an intellectual teaching act is to achieve awareness, rather than learning. Komisar argues also that the intention of the act should be made clear to the pupil and the awareness should be achieved "by identifying the reasons given as the intelligible grounds for the point the students are to become aware of."[4] His entire argument is testimony to his concluding statement:

> Indeed, to think of the teaching enterprise as somehow primal and every other sense of teaching as derivative is to get the matter reversed. The strictest, the basic, the keenest concept of teaching we have is the concept we apply to designate particular occurrences of intellectual acts directed to the auditor.[5]

While this brief account of the article is a disservice to Komisar's precise and vivid style of argumentation, it does capture the most relevant points. Komisar sees teaching as an activity which seeks to achieve a pupil's awareness of a point by the explicit provision of reasons which support and establish the point.

By a different route, similar conclusions are reached by Thomas F. Green in his book The Activities of Teaching.[6] Noting that teaching seems to be

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[1] B. Paul Komisar, "Teaching: Act and Enterprise," in Concepts of Teaching: Philosophical Essays, ed. by C. J. B. Macmillan and Thomas W. Nelson (Chicago: Rand McNally & Company, 1968), pp. 63-88.

[2] The need to specify an "enterprise sense" of teaching is to cover cases where its usage might be thus: "I am teaching (enterprise sense) this period, but I'm not teaching (act sense) just now--I'm giving a quiz."

[3] Ibid., pp. 68-75.

[4] Ibid., p. 80.

[5] Ibid., p. 88.

[6] Thomas F. Green, The Activities of Teaching (New York: McGraw-Hill Book Company, 1971).

concerned with the acquisition or modification of beliefs, Green suggests that beliefs are acquired or modified as "parts of a belief system."[1] His analysis of teaching is based upon the examination of this metaphor of belief systems.

Green distinguishes between what beliefs are held and how they are held by considering first the relations between beliefs, and then the relation between beliefs and the grounds which support them. In considering relations between beliefs, Green sees three dimensions of belief systems: (1) quasi-logical, on which some beliefs are primary and others are derivative; (2) psychological, on which beliefs are held with varying strength depending upon how essential they are to the individual; and (3) cluster-protective, on which beliefs are isolated and protected from relationships with other clusters.[2] In considering the relation between beliefs and grounds for their support, Green points out that beliefs can be held either evidentially or non-evidentially. When beliefs are held non-evidentially, they are held without regard for reasons, evidence, or the standards by which reasons and evidence are evaluated.[3]

Green's analysis, like Komisar's, directs attention to reasons and grounds for points or conclusions. Green reminds us that alternatives to rational argument are available to pupils. The analysis implies that pupils may vary in their psychological willingness to call certain beliefs into question and in the extent to which they hold particular beliefs on the basis of reasons and evidence. From these distinctions about the bases for beliefs, Green proceeds to argue that "instruction" attempts to establish beliefs that are held on the basis of reasons and evidence, while "indoctrination" is concerned not with the basis but with the content of the beliefs it attempts to establish. Like Komisar, Green would have teachers take "instruction" as the culturally desirable way to understand "teaching."

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[1] Ibid., p. 42.

[2] Ibid., pp. 44-48.

[3] Ibid., p. 48.

Reasons and Authority in Education

In Authority, Responsibility, and Education,[1] R. S. Peters considers the development of the concept of authority in Western culture in terms of Weber's analysis of three different authority systems, identified as "legal-rational," "traditional," and "charismatic." Peters stresses what he takes to be a fundamental distinction between rational and traditional "attitudes toward authority"--a distinction which may be compared to that between "having good reasons" and "taking someone else's word."[2] Clearly, persons can have such attitudes while arguments cannot, but arguments can reflect or suggest one or another kind of authority.

Peters' discussion of the development and increasing influence of science and morality illustrates the extent to which Western thought and culture have come to depend upon reasons rather than tradition. By speaking of science and morality as "anti-authoritarian" developments, Peters indicates that accepting an idea on the basis of reasons is a point of view which contrasts with a traditional pattern of accepting an idea on the basis of the power or position of its proponent.[3] When applying the analysis of authority to some current issues in education, Peters argues that the manner in which a teacher passes on "traditions, skills, and information" has direct consequences for how pupils come to regard these.[4] The discussion suggests the conclusion, quite consistent with that of Komisar and Green, that rational rather than traditional authority is more desirable and appropriate in Western education.

In Ethics and Education,[5] Peters carries this analysis further and describes the teacher as an authority figure in two senses. A teacher is in authority to do a certain job and he is an authority on some aspect of the culture of the community.[6] Generally we think of a teacher as an authority

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[1] R. S. Peters, Authority, Responsibility, and Education (New York: Atherton Press, 1967).

[2] Ibid., pp. 13-24.

[3] Ibid., pp. 25-38.

[4] Ibid., pp. 96-107.

[5] R. S. Peters, Ethics and Education (London: George Allen & Unwin Ltd., 1966).

[6] Ibid., p. 240.

by virtue of his knowledge of a discipline or skill; a teacher is usually placed *in* authority according to criteria which include evidence of his status as *an* authority.

That a teacher is *an* authority seems to entail an intellectual responsibility that his teaching be consistent with the public knowledge he has studied. That a teacher is *in* authority seems to entail a social responsibility that his teaching will be acceptable to the community which supports his being in authority. These two senses of authority are very different in kind: being *an* authority refers to a teacher's knowledge, while being *in* authority refers to a teacher's position (in Komisar's "occupation" sense). As Peters notes, knowledge requires supporting reasons and public procedures for testing them, and it does not depend "upon the appeal to particular men."[1]

A teacher's authority bears directly upon the statements he makes when he is teaching (in Komisar's "act" sense). Intellectually, a teacher's knowledge as *an* authority in his subject enables him to give reasons for his statements, and hence rational authority to his arguments. Socially, a teacher's position *in* authority enables him to "get away with" not giving reasons, thereby suggesting traditional authority for his argument.

A Scheme for Studying Arguments

The preceding sections have identified the general problem under consideration, but they are not sufficient to prepare us to examine statements made in classrooms. One would expect to find conclusions, or "points to become aware of," in almost any instance of teaching. One would also expect to find reasons and evidence being used by individuals in classrooms. Nor would one be surprised to find individuals making statements on their own authority, without provision of reasons. Nevertheless, an initial examination of a number of science lesson transcriptions indicated that these terms do not discriminate sharply enough to establish conclusions about the kind of authority a classroom argument suggests.

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[1] *Ibid.*, p. 251.

Toulmin's Argument-Pattern

What seems to be needed here is a framework for looking at arguments in general, so that the use of reasons and evidence can be assessed in relation to the specific subject matter of the lesson being studied. Such a framework is described by Stephen Toulmin in The Uses of Argument.[1] In his introduction, Toulmin indicates that the book is an attempt "to characterise what may be called 'the rational process', the procedures and categories by using which claims-in-general can be argued for and settled."[2] Using the field of jurisprudence to guide his consideration of rational arguments in general, Toulmin develops a framework in response to the problem of "how we are to set out and analyse arguments in order that our assessments shall be logically candid--in order, that is, to make clear the functions of the different propositions invoked in the course of an argument and the relevance of the different sorts of criticism which can be directed against it."[3]

In a chapter titled "The Layout of Arguments," Toulmin seeks a pattern of analysis which can answer the question "What, then, is involved in establishing conclusions by the production of arguments?"[4] Toulmin first distinguishes between the claim or Conclusion (C) and the facts or Data (D) which support the claim. His second distinction identifies statements of the type "Given data D, one may take it that C." Such statements are referred to as Warrants (W) for their function of justifying the move from Data to Conclusion.[5] Toulmin represents his basic "pattern for analysing arguments" with this diagram.

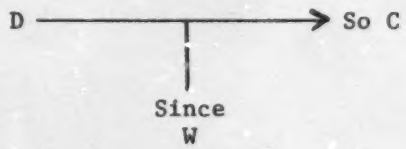

Figure 1. The Basic Argument-Pattern[6]

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[1] Stephen Toulmin, The Uses of Argument (Cambridge: Cambridge University Press, 1958).

[2] Ibid., p. 7.

[3] Ibid., p. 9.

[4] Ibid., p. 97.

[5] The words "Data," "Conclusion," and "Warrant" begin with a capital letter in this paper, when used in the sense given them by Toulmin.

[6] Toulmin, The Uses of Argument, p. 99.

Having developed this basic pattern, Toulmin makes a comment which speaks directly to the present intention to examine the use of reasons in teaching:

> . . . unless, in any particular field of argument, we are prepared to work with warrants of some kind, it will become impossible in that field to subject arguments to rational assessment. The data we cite if a claim is challenged depend on the warrants we are prepared to operate with in that field, and the warrants to which we commit ourselves are implicit in the particular steps from data to claims we are prepared to take and to admit.[1]

To the basic pattern Toulmin next adds modal Qualifiers (Q) which indicate the degree of force with which the Data support the Conclusion. In his words, "Warrants are of different kinds, and may confer different degrees of force on the conclusions they justify."[2] These Qualifiers signal the difference between a Warrant which leads "necessarily" to the Conclusion and a Warrant which permits one to move only tentatively from Data to Conclusion, as would be indicated by the word "probably." Next in the pattern come "conditions of exception or rebuttal (R)," which correspond to such issues in the jurisprudence analogy as whether there are special facts limiting the application of a law in a particular case.[3] With these additional elements, the pattern has this form.

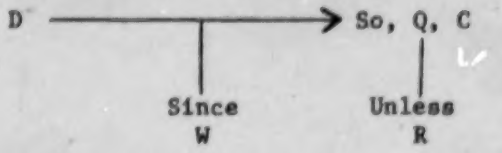

Figure 2. The Argument-Pattern Elaborated[4]

Toulmin's own words summarize his analysis most effectively.

> Just as a warrant (W) is itself neither a datum (D) nor a claim (C), since it implies in itself something about both D and C--namely, that the step from the one to the other is legitimate; so, in turn, Q and

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[1] Ibid., p. 100.

[2] Ibid.

[3] Ibid., pp. 100-101.

[4] Ibid., p. 101.

> R are themselves distinct from W, since they comment implicitly on the bearing of W on this step--qualifiers (Q) indicating the strength conferred by the warrant on this step, conditions of rebuttal (R) indicating circumstances in which the general authority of the warrant would have to be set aside.[1]

One more element completes the pattern. Toulmin has observed that the acceptability of the particular Warrant employed in an argument may be challenged, and he offers the term "Backing" (B) to identify the kinds of statements made to defend Warrants.

> In addition to the question whether or on what conditions a warrant is applicable in a <u>particular</u> case, we may be asked why <u>in general</u> this warrant should be accepted as having authority. . . . Standing behind our warrants, . . . there will normally be other assurances, without which the warrants themselves would possess neither authority nor currency--these other things we may refer to as the <u>backing</u> (B) of the warrants.[2]

Toulmin notes that while Data and Warrant must be explicit in order to argue to a Conclusion, it is often the case that the Backing[3] for the Warrant being used remains implicit, at least initially and before the argument is challenged. The Backing for a Warrant may be a statement of fact; it is the Warrant which then tells us how we may argue in view of that fact. In other words, "Backing" refers to the facts which authorize the Warrant which permits an inference from Datum to Conclusion.[4] Toulmin suggests that Backing is related to the other elements of an argument as in the following diagram.

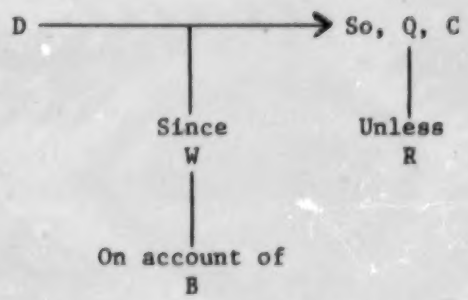

Figure 3. The Complete Argument-Pattern[5]

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[1] <u>Ibid.</u>

[2] <u>Ibid.</u>, p. 103.

[3] The words "Backing," "Qualifier," and "Rebuttal" begin with a capital letter in this paper, when used in the sense given them by Toulmin.

[4] Toulmin, <u>The Uses of Argument</u>, pp. 103-106.

[5] <u>Ibid.</u>, p. 104.

Significance of Backing for Warrants

The idea of Backing for Warrants is a very important one for Toulmin, but the distinction between the two is not commonly employed. Some clarification should result from the identification and discussion of Backing in the science teaching episodes analyzed below. But prior to that analysis it will be helpful to consider the examples used by Toulmin, especially since he uses them also to illustrate how the kind of Backing which can authorize a Warrant differs between fields of argument.

Toulmin presents three Warrants which might be used to move from Datum to Conclusion in an argument: (1) "A whale will be a mammal," (2) "A Bermudan will be a Briton," and (3) "A Saudi Arabian will be a Muslim."[1] He then points out how very different are the Backings which can authorize these three Warrants. The first Warrant is supported by a scheme of taxonomic classification, the second Warrant is based upon a particular set of legal statutes, and the third Warrant is backed by statistics which relate nationality and religious beliefs.[2]

These simple examples illustrate how the Backing for a Warrant differs from the Warrant itself and also how Backings differ between fields of argument. All of these considerations speak to the use of Warrants in arguments. It is also necessary to consider the establishment of Warrants.

Warrant-Using and Warrant-Establishing

Toulmin suggests that "Warrant-using" arguments be distinguished from "Warrant-establishing" arguments. In the former class, a Conclusion is being established from Data by citing an acceptable Warrant. In the latter class, a new Warrant is being established by demonstration of its successful application in a number of instances of verified Datum and Conclusion. This distinction may be compared to that between deduction and induction, respectively.

Discussion of the role of Backing in the development of Warrant-establishing arguments would probably help clarify the meaning of Backing and mark the special features of Warrant-establishing arguments, but Toulmin's

[1] Ibid., p. 103.

[2] Ibid., p. 104.

presentation does not include such discussion. It would seem that the facts or statements which constitute Backing would have some influence upon the collection and selection of instances of verified Datum and Conclusion to establish a new Warrant. The suggestion here is that one has to have a need for the new Warrant--some problem in the particular field of argument--and that the Backing which will authorize the new Warrant guides how one looks for and interprets instances which will establish the Warrant. In other words, the facts which make up the Backing guide the selection of instances which serve to show that the new Warrant "works."

Once a Warrant has been established, the Backing is implicit in the use of the Warrant to establish Conclusions. Clearly, Backing plays a more crucial role in establishing a Warrant than in using an established Warrant to draw a Conclusion from Data. This interpretation of the significance of Backing seems consistent with a statement in the discussion which follows the presentation of the argument-pattern. Toulmin describes the "transition from Backing to Warrant" as the transition "from the factual information we are presupposing to the inference-licence which that information justifies us in employing."[1]

Summary

Komisar and Green have argued that the meaning of teaching implies the provision of reasons and evidence for the claims presented to pupils. Peters has argued that an individual's attention to reasons and evidence suggests a rational attitude toward authority for claims, and that this may be compared with a traditional attitude toward authority, by which an individual accepts claims according to the position or power of those who make them. This investigator is using the same distinction for characterizing arguments developed in science lessons.

Because a teacher is an authority in authority, teaching has the potential for suggesting either kind of authority. Being an authority enables one to convey rational authority in argument, but being in authority permits one to convey traditional authority in argument. There is obvious potential for authority conflict in the arguments a teacher develops. The kind of

[1] Ibid., p. 112.

authority which gives force to a teacher's arguments must be communicated clearly to pupils if confusion about authority for arguments is to be avoided.

A scheme developed by Toulmin for analyzing arguments has been described and is used in the analysis of teaching episodes in Chapter II. Toulmin's argument-pattern contains six elements--Data, Warrant, Conclusion, Backing, Qualifier, and conditions of Rebuttal. The first four of these elements will be important in assessing the use of reasons and evidence. Toulmin also calls attention to the existence of two classes of arguments: Warrant-using, which support Conclusions; and Warrant-establishing, which support Warrants.

In Chapter II, three teaching episodes from science lessons are analyzed to determine which kind of authority is giving force to each argument. The analysis includes the following.

1. Identification of distinct arguments, to divide an episode into segments containing single arguments.

2. Classification of teacher and pupil statements using the elements of Toulmin's argument-pattern to identify the functions of statements in an argument.

3. Consideration of the source of the authority for each element and the relationship of elements to each other, with special attention to the Backing for the Warrant being established or used.

4. Determination of the kind of authority conveyed or suggested by each argument.

The essential idea is that <u>how</u> a teacher guides an argument suggests one or another kind of authority. Were a teacher only <u>an</u> authority, and not <u>in</u> authority, his pupils would have no rational basis for accepting a claim if the argument omitted an element, related elements incorrectly, or failed to identify the source of the Backing. Hence any of these conditions in an argument will be taken as suggesting traditional authority. In order to suggest rational authority by his argument, a teacher would provide all elements in correct relationship and trace the Backing to its source in the discipline.

CHAPTER II

ANALYSIS OF THREE SCIENCE TEACHING EPISODES

The nature of authority in teaching has been discussed in terms which distinguish between traditional authority and rational authority. An examination of the importance of reasons and evidence in teaching led to the presentation of a six-element "argument-pattern" for studying arguments. In this chapter these theoretical considerations are applied in the analysis of three science teaching episodes.

Procedure

The three episodes analyzed below were selected from a set of twelve science lessons recorded in Ontario schools during the spring of 1971. The teachers and pupils in the lessons remain anonymous, of course, and no judgments of personal teaching styles are intended.

Each episode is analyzed in a three-column format which permits the simultaneous presentation of (1) the transcription of the episode as recorded in the lesson, (2) the identification of elements of Toulmin's argument-pattern, and (3) brief comments about how the elements are being used in the arguments being developed. In the "Pattern Element" column two letters are used in addition to Toulmin's categories: the letter "S" (for "solicits") indicates that one speaker is asking another to provide an element of an argument, while the letter "J" (for "judges") indicates that one speaker is evaluating another speaker's provision of an element of an argument.

The reader will note in each transcription that the discussion proceeds in stages as one argument leads into another. Separate arguments within each episode are termed "segments," and the beginning of each segment of an episode is noted in the "Comments" column. Each analysis of an episode is followed by a commentary which develops and extends the initial three-column analysis. The commentary describes the manner in which teacher and pupils contribute to the argument contained in each segment of the episode. Each

commentary also explains which kind of authority is suggested by the segments of the episode.

An Example of Analysis

To complete the preparation for an analysis of three episodes of science teaching, a brief passage from one of the episodes is analyzed in detail. This sample analysis is intended to further clarify the criteria being used to identify elements of the argument, and the criteria being used to identify the kind of authority an argument suggests.

Transcriptions in this study show the teacher influencing most statements which are made during lessons. This is a natural consequence of the teacher's knowledge and position. From the present perspective of the analysis of arguments, the teacher is generally responsible both for introducing and for closing a particular argument, although instances occur in which a pupil begins an argument subsequently developed by the teacher or another pupil. An obvious preliminary step in the present analysis is the organization of the transcription into its constituent arguments by noting the points at which one argument ends and another begins. Teacher statements usually provide the clearest indications of such transitions.

In the three episodes analyzed in this chapter, each segment of an episode is a single argument, while each episode consists of a series of closely related arguments. For the immediate purpose at hand, to demonstrate the analysis of an argument in a science lesson, the first thirty lines from Episode A are presented below and followed by detailed discussion.

The Sample Passage from Episode A

TRANSCRIPTION	PATTERN ELEMENT	COMMENTS
Teacher: Okay. We were talking about the electric charges on different kinds of objects. What changes take place in an ebonite rod when it's rubbed with wool? (Pause) Only two people? Dave.		*SEGMENT A-1 BEGINS*
	Data	
	S. Conclusion	Teacher solicits Conclusion
Dave: Er, it received electrons from the wool.	Conclusion	

	Teacher: Right. It received electrons from the wool. Er, can you suggest any	J. Conclusion	Teacher judges Conclusion
15	reason why the electrons moved from the wool over on to the ebonite? Brad.	S. Warrant	
	Brad: There's a shortage of electrons on the ebonite rod and there's a surplus	Backing and Data	A Warrant that electrons move from surplus to shortage seems implicit
20	on the wool, so they move to the greater...	Conclusion	here
	Teacher: There's some people shaking their heads. Er, Gary, would you disagree	J. Backing S. Warrant	Teacher's statement tells pupil he was incorrect Wording implies a different account is required
25	with that?		
	Gary: Well it must be... the atoms on the wool... the electrons on it are... repelled from the nucleus,	Backing	This incomplete Backing alludes to how electrons behave in atoms
30	so they want to move...	Warrant	

Criteria for Identifying Elements of an Argument-Pattern

When the limits of a single argument have been established, the statements of the speakers are studied in relation to that argument. Statements by the teacher are very often ones which solicit, provide, or judge an element of the argument. Statements by pupils are very often ones which contain logically appropriate responses to statements by the teacher. Frequently an argument is begun by the teacher's introduction of Data and solicitation of either a Conclusion or a Warrant related to the Data. Such is the case in lines 1-8 above in which the teacher introduces a topic and situation (Data) and asks what will happen (solicits a Conclusion). Dave's response in lines 9-10 is a clear statement of a Conclusion.

Recalling the discussion of arguments in Chapter I, such a step from Data to Conclusion uses a Warrant, and in lines 11-16 the teacher first judges the Conclusion and then solicits a Warrant which permits that Conclusion to be made. In lines 17-30, two pupils respond to the teacher's question. Both responses are unsuccessful in the eyes of the teacher, and analysis of those responses as elements of the argument helps to explain their failure. Brad, who speaks in lines 17-21, does not provide a Warrant but jumps to the Conclusion from certain Warrant-supporting statements (Backing).

The teacher uses signs of disagreement from other pupils as support for his judgment in lines 22-25 that Brad's statement is incorrect. In lines 26-30, Gary's response has elements which seem to be incomplete statements of Backing and Warrant.

It should be noted that the identification of elements of an argument frequently requires several trial-and-error stages before all the elements seem to relate properly to each other within the particular argument. Of course it is just this sense of proper relationship which helps to define a valid argument. In the classroom situation, where many individuals often participate in a single argument, it is usually not immediately obvious how each statement relates to those before and after, and to the argument being made.

Criteria for Identifying the Kind of Authority Suggested

In Chapter I, it was suggested that the authority for an argument may appear to be derived from a teacher's position, if it is not made clear how the authority is derived from the particular discipline of instruction. Toulmin's pattern of elements of an argument indicates the types of statements which must be provided and the relationship among those statements which must be demonstrated in order to achieve a complete argument. Toulmin also suggests that it is the Backing in particular which will reflect the nature of the discipline. Hence the discipline and not the position is suggested as the authority for an argument, when the logical relationship among elements of the argument is clear, and when the Backing for the Warrant is identified and traced back to the discipline of instruction. In this particular passage, the discipline is that of natural science.

In these terms it is possible to make tentative identification of the kind of authority suggested by the above thirty-line passage. Clearly this can be only tentative, since the passage is not a complete segment containing all the discussion given to this argument. However, this passage will serve to illustrate the considerations involved in identifying the kind of authority suggested.

Dave's Conclusion (lines 9-10) is a clear, specific response to the teacher's question. When the teacher judges the Conclusion to be correct, he solicits a suitable Warrant (lines 11-16). By making a judgment before

the Warrant is available, the teacher seems temporarily to support the Conclusion with the authority of his position. Brad's reply (lines 17-21) suggests that he does not understand what kind of statement will serve as a Warrant. His response seems to imply that electrons move from surplus to shortage, in which case the identification of a shortage on the ebonite and a surplus on the wool represents both Data (where they occur) and Backing (that they occur) for the implied Warrant.

The teacher's negative judgment (lines 22-25) is again one based upon position, supplemented by the disagreement of other pupils. This interpretation is made on the observation that Brad's statement is not assessed according to the Warrant-function it should have served. Instead, Gary is invited to speak. His contribution (lines 26-30) suggests that electrons will move because they are being repelled. Gary's reference to "atoms" and "nucleus" seems to be a very incomplete statement of Backing for his Warrant.

Had they previously been made aware of appropriate Backing, both Brad and Gary would be in error for giving Backing which is not consistent with natural science. To this point, the statements of the argument seem to suggest traditional authority. When the segment ends and the argument has been completed, more confident judgment of the kind of authority suggested by this argument can be defended.

The Role of the Discipline in the Analysis

The identification of elements of an argument and the kind of authority given for them can be assisted by reference to the complete argument as it might be stated within the body of scientific knowledge. In this particular argument the Data would include the names of the two materials, wool and ebonite, as well as the description of their being rubbed together and studied for subsequent changes in electric charge. The Conclusion is that the ebonite receives electrons from the wool, as Dave stated (lines 9-10). An applicable Warrant for this step might state that ebonite attracts electrons more strongly than wool when the two materials are rubbed together. The Backing for this Warrant would include the atomic model of matter--a positive nucleus surrounded by shells of negative electrons, those in the outermost shell being somewhat free to move. The Backing would also explain

how charges are acquired by certain materials, given the atomic model of matter.

Setting out the argument from the discipline in this fashion can guide the identification of elements of argument in statements in a transcription. Both the interrelationship of the parts of the argument and the relationship of the Backing to that supplied by the discipline guide the identification of the kind of authority being suggested by the argument.

Analysis of Episode A

This episode is taken from the beginning of a lesson (pages 1-4 in a transcription of 24 pages) on the topic "static and current electricity." There are twenty pupils in this Grade 10 class (twelve boys, eight girls), and the lesson occurs late in the school year (May 1971) during a period in the afternoon--1:15 until 2:00.

	TRANSCRIPTION	PATTERN ELEMENT	COMMENTS
	Teacher: Okay. We were talking about the electric charges on different kinds of objects. What changes	Data	*SEGMENT A-1 BEGINS*
5	take place in an ebonite rod when it's rubbed with wool? (Pause) Only two people? Dave.	S. Conclusion	Teacher solicits Conclusion
	Dave: Er, it received	Conclusion	
10	electrons from the wool.		
	Teacher: Right. It received electrons from the wool. Er, can you suggest any	J. Conclusion	Teacher judges Conclusion
15	reason why the electrons moved from the wool over on to the ebonite? Brad.	S. Warrant	
	Brad: There's a shortage of electrons on the ebonite rod and there's a surplus	Backing and Data	A Warrant that electrons move from surplus to shortage seems implicit
20	on the wool, so they move to the greater...	Conclusion	here
	Teacher: There's some people shaking their heads. Er,	J. Backing	Teacher's statement tells pupil he was incorrect
25	Gary, would you disagree with that?	S. Warrant	Wording implies a different account is required

Gary: Well it must be... the atoms on the wool... the electrons on it are... repelled from the nucleus, so they want to move...	Backing Warrant	This incomplete Backing alludes to how electrons behave in atoms
Teacher: You people at the back hear? Cathy. Better repeat that Gary, please.		Teacher controlling speaker
Gary: Well the, the electrons in the wool like, they are far out from the nucleus so they have a tendency to move.	Backing and Warrant	
Teacher: Er, possibly. Someone else explain why the electrons move from the wool over on to the ebonite. Mary Jo.	J. Warrant S. Warrant	"Possibly" seems to imply "no"
Mary Jo: Um, the ebonite rod has, er, like positives that have stronger pull on them. And, like, the friction between them makes the positives attract more.	Warrant Warrant	Pupil indicates two aspects of a justification of the Conclusion
Teacher: All right. Apparently, or possibly, the ebonite has a stronger attraction for electrons than the wool, so that when we rub the two together the electrons move from one over on to the other. Okay Brad? Going to change your theory?	J. Warrant; repeats Warrant, Data, and Conclusion	Purpose of "possibly" is not clear Teacher repeats only one aspect of the Warrant presented by pupil Teacher indicates how Warrant implies Conclusion
Brad: Umhm.		
Teacher: How do we know that your theory wasn't correct? What was the one thing that he forgot?		Teacher indicates Brad had one error in his argument
Pupil: That, um, the...the ebonite rod is neutral and you had the same amount of, er, er, positive as negative.	Backing	
Teacher: Okay. You started out with each of them in the neutral state so they would have the same. All right, then we say that one of	J. Backing	The error in Backing is treated as a simple feature of initial Data

those two substances has a stronger attraction for electrons than the other. Therefore it would be possible to take a list of substances and arrange them in a list, or in an order, which would, er, put those which have, say, a strong attraction for electrons on top of the list and those with a weak attraction for electrons at the bottom of the list. So we have such a list here--you'll notice that some of the materials that we have listed here we've used in the experiments that we've been doing. The first one, for example, glass...(writing on the board, "Glass, Wool, Cat's fur, Silk, Cotton, Paraffin wax, Ebonite, Rubber, Sulphur"). Okay. Now, I'm going to tell you this about the list: as we go down the list there is increasing ability to hold electrons. (An arrow is drawn pointing down the list with the label, "increasing ability to hold electrons.") Now what does that mean when we compare, say, cat's fur and paraffin wax? Jerry.	Warrant	Warrant now stated to Teacher's satisfaction *SEGMENT A-2 BEGINS* This list combines a number of specific Warrants into one general Warrant Teacher states Warrant Teacher writes Warrant on the blackboard, and *SEGMENT A-3 BEGINS*
	S. Conclusion	
Jerry: The paraffin wax will hold electrons better than cat's fur?	Warrant	Conclusion is implicit
Teacher: Er, better? Can we get another word there?	J. Warrant	Teacher takes issue with pupil's wording
Jerry: Er, more?		
Teacher: More strongly. All right, this list is called an electrostatic series (writing, "Electrostatic Series"). And I think you can now see the	Names general Warrant	Teacher changes wording to conform to his statement in line 74 above, although pupils have used wording written on blackboard (line 105)

	use of an electrostatic series. Before we just memorized that ebonite		
125	became charged negatively when it was rubbed with wool. If we look at this list and notice the position		*SEGMENT A-4 BEGINS*
130	of wool and ebonite, if we rub these two substances together what's going to happen?	S. Conclusion	
	Pupil: You get a negative charge.	Conclusion	Response is not complete, since location is not specified
135	Teacher: Why?	S. Warrant	
	Pupil: Because there is, um,...because most, more er, electrons go on to the rod.	Data and Conclusion	Now pupil indicates the location, but teacher has requested Warrant
140	Teacher: Why would more electrons go from the wool to the rod than the other way?	S. Warrant	
	Pupil: Because the wool's	Data and	Pupil continues to reply
145	lose them...wool will lose them.	Conclusion	with mixture of Data and Conclusion
	Teacher: Why would the wool lose the electrons? You're not answering why. (No	S. Warrant	Teacher indicates pupil is not answering his question
150	response) Steve, or er, Jerry rather.		Teacher turns to another pupil
	Jerry: Er, er, the ebonite will hold more electrons so it'll take it out of the	Warrant	
155	wool.		Again Teacher seems to accept Warrant while questioning wording
	Teacher: Will hold more?		
	Jerry: Er, take more away.		Pupil changes his wording
	Teacher: You're missing the one word, I think, that	J. Warrant	Teacher indicates extent and significance of change
160	explains it properly. Gary?		required
	Gary: The ebonite will hold the electrons...		Another pupil uses the word "hold"
	Teacher: ...or strength		Teacher repeats his use of
165	with which they hold the electrons. Okay, let's see if we can use this then.		"strength," as in lines 74 and 116 above
			No Backing or elaboration is provided

Commentary on the Analysis

Episode A is the opening portion of a lesson in electricity. The discussion is based upon previous study of materials which can be used to demonstrate phenomena of static electricity. Later in the lesson the teacher shifts the topic to current electricity.

The discussion in this episode uses Warrants introduced in previous lessons. Arguments in the episode suggest its division into four segments: (A-1) applying a specific Warrant for ebonite and wool, (A-2) establishing a general Warrant for nine materials, (A-3) applying the general Warrant to cat's fur and paraffin wax, and (A-4) applying the general Warrant to ebonite and wool. The argument in the first segment (A-1, lines 1-75) establishes a context for viewing the remaining three segments; it is therefore important to examine this first segment quite carefully. Data and Conclusion for the argument are present at the outset, and most of segment A-1 involves a search for a suitable Warrant.

A complete description of the flow of the argument will facilitate subsequent interpretation of statements for the kind of authority suggested. The teacher opens the lesson by reminding his pupils of a previous discussion and then asking them to provide a particular Conclusion about changes in ebonite when rubbed with wool. A Conclusion offered by Dave is approved and repeated by the teacher (lines 11-12). When the teacher asks for a Warrant which would permit that Conclusion to be made, Brad responds with a statement of Data and Backing which leaves the Warrant implicit (lines 17-21). Gary offers both Warrant and Backing (lines 34-37), to which the teacher comments "possibly" before calling on a third pupil. When Mary Jo puts forth two Warrants (lines 43-45 and 46-48), the teacher indicates his approval but repeats only the first Warrant, in words (lines 49-50) which suggest that there might still be some doubt about the Warrant. After indicating to Brad that his error was in his statement of the initial situation (lines 56-71), the teacher ends the first segment by repeating the Warrant without reservation (lines 71-75).

The first opportunity for an interpretation in terms of authority comes at line 11, where the teacher supports a Conclusion with the authority of his position, presumably until a valid Warrant for the Conclusion is stated. Such a Warrant could have been established on rational authority in a previous

lesson, and the Backing would include the discipline's way of looking at the phenomena being explained. (Certainly the Conclusion in this segment is not of the type which can be verified independently by simple inspection of the ebonite rod.)

Brad's implicit Warrant and Gary's more explicit Warrant are each rejected in ways which suggest traditional authority (lines 22-25 and line 38). This interpretation is indicated by the absence of any discussion of their statements in terms of Backing or of their suitability as Warrants. Mary Jo's response, which has two parts, is supported by the teacher on the authority of his position in line 49. In lines 50-56 the teacher restates part of her response as a Warrant, by relating it to the step from Data to Conclusion. When Brad's response is reconsidered in lines 60-71, the teacher indicates that Brad was mistaken about the initial condition of the two materials. The discussion of Brad's mistake, which refers to only one feature of the Backing for the Warrant, is the single instance in which the teacher gives a reason for his judgment of a pupil's response. This discussion falls short of establishing the role of the information in lines 64-71 as Backing for the Warrant.

It is interesting that Segment A-1, an instance of Warrant-using, is devoted almost entirely to obtaining a clear statement of the Warrant required for Dave's Conclusion in lines 9-10. Backing and Warrant are mixed and confused in the discussion, and the contribution of the Backing to a correct statement of the Warrant is not made clear. For this reason, and because no reference is made to previous lessons in which this Warrant was established, the judgment is made that traditional authority predominates in segment A-1.

Only the teacher speaks in the second segment (A-2, lines 76-106). He establishes a new, more general Warrant by extending the Warrant just discussed to include nine materials, any two of which can be used to produce the separation of electric charges. This new Warrant summarizes a number of specific Warrants which we must assume, for present purposes, to have been established in previous lessons. No judgment can be made about the kind of authority which predominates during this establishment of a general Warrant. Such judgment would require reference to the arguments for the Warrants summarized in the new Warrant, and no evidence is available for this purpose.

Analysis of the arguments in the third and fourth segments of the lesson requires reference to the particular words used by the teacher in the second segment. When he first proposes the general Warrant (lines 76-86), the teacher speaks in terms of "strength of attraction for electrons." However, once he has presented the list of materials (lines 94-97) to which the new Warrant can be applied, he states the Warrant in terms of "ability to hold electrons" (lines 99-102) and writes this same phrase on the board beside the list (lines 102-106).

In the third segment of this episode (A-3, lines 106-127), a pupil is asked to apply the general Warrant to a particular pair of materials. Jerry's response (lines 110-112) is in the form of a specific Warrant about the two materials. It leaves implicit the desired Conclusion that paraffin wax will attract electrons from the fur, thereby acquiring a negative charge. No reasons are given for the teacher's preference for the phrase "more strongly" (line 116), emphasized before he labels the list as an "Electrostatic Series" and refers to the value of the general Warrant.

The fourth and final segment of this episode (A-4, lines 127-167) is similar in pattern to the third. In both segments the teacher solicits a Conclusion based on the general Warrant, and then solicits a statement of the particular Warrant for the Conclusion. The fourth segment is interesting because there are several points of confusion which are not resolved before the episode ends. The teacher asks that the list be used to predict the results of rubbing ebonite with wool--the same two substances already discussed in the first segment. A pupil's Conclusion (lines 133-134) is incomplete, but the teacher moves at once to ask what Warrant the pupil used (line 135). The pupil replies twice with aspects of Data and Conclusion, and the teacher twice repeats his request for an appropriate Warrant (lines 136-148). After stating "You're not answering why" (lines 148-149), the teacher calls on Jerry who supplies a Warrant using the particular word "hold." As in segment A-3, the teacher challenges the choice of words (lines 156-161) and finally inserts the word "strength" (line 164).

Two important issues are not resolved in this segment. First, the teacher has not explained to the pupil who could not supply the desired Warrant (lines 133-146) the nature of the difference between his statements (Data and Conclusion) and the kind of statement (Warrant) being solicited.

Second, the teacher has twice insisted that the particular word "strength" be included in the statement of the Warrant, but this usage has been supported only by the authority of his position. In the absence of any explanation of the special contribution of this word to the role of the Warrant in the argument, the pupils have apparently used the word "hold" because it was written on the blackboard in front of them (lines 105-106).

As this lesson continues beyond the episode here chosen for analysis, the teacher poses further instances in which the pupils are to draw Conclusions about the behavior of pairs of these materials, but he no longer solicits statements of supporting Warrants. Segments A-1, A-3, and A-4 seem to share a pattern in which the teacher concludes that the pupils are <u>using</u> Warrants correctly, and therefore should be able to <u>state</u> the Warrants they have used. Each time, traditional authority seems to predominate in the teacher's attempt to have the Warrant <u>stated</u> in a particular way. He does not seem to recognize the potential contribution of the Backing for these Warrants to resolution of difficulties pupils have in stating the Warrants in the desired form.

Analysis of Episode B

This episode is taken from the middle of a lesson (pages 9-11 in a transcription of 18 pages) on the topic "ratio of angle of incidence and angle of refraction." There are twenty-one pupils in this Grade 9 class (nine boys, twelve girls), and the lesson occurs late in the school year (May 1971) during a period in the morning--10:10 until 10:50.

	TRANSCRIPTION	PATTERN ELEMENT	COMMENTS
	Teacher: Okay, here we have our results on the side board. (The table reads:		*SEGMENT B-1 BEGINS*
	10° 7°	Data	
5	20° 13°	(left column)	
	30° 19°	and	
	40° 26°	Conclusions	
	50° 31°	(right column)	
	60° 36°		
10	70° 40°)		
	Can anyone see a relationship between the angle of incidence and the angle of refraction	S. Warrant	Teacher solicits Warrant

from those results? Just look at that for a couple of minutes. (Pause. He writes "SNELL'S LAW") Susan.		
Susan: Um, when the angle of incidence increases by 10, most of the angles of refraction increase by 6.	Warrant (with qualifier)	
Teacher: That's interesting. As the angle of incidence increases by 10, the angle of refraction increases by 6. Let's see: 7 from 13 is 6, 13 from 19 is 6, there's 7, there's 5, there's 5,... there's 4.	Warrant	Teacher restates Warrant, omitting Qualifier Teacher examines Backing for Warrant and finds it weak
Susan: Well, the average is 6.	Warrant	Pupil attempts to save her Warrant
Teacher: Oh, well averages aren't good enough here (some laughter). Rick.	J. Warrant	Teacher judges Warrant unsuitable
Rick: The, er, like, first of all when you increase it by 10, er there's an increase of...there's a...first of all 7, then it goes down to 6, then it goes down to 5, and then it goes down to 4.	Warrant	*SEGMENT B-2 BEGINS*
Teacher: So what?	J. Warrant	Teacher seems to imply Warrant is "obviously" inadequate
Rick: If you take the difference, like er, from 6 to 7 you've got a difference like 10--like you've got... this, er, goes back to 4 degrees of difference between 36 and 40. And between the 31 and the 36, we have to have a 50 and 60 increase by 10, and then you have 5. And then at 26 and 31, and that's 5. And then you go 6...like. (Laughter)	Backing for Warrant	
Teacher: You're just telling me the results up here. What, what...	J. Backing	Teacher seems to say that pupil has not provided either Warrant or Backing, but is simply reporting Data
Rick: Yeah, well er, you said, um, see this 5 thing, when the		

	angle of incidence increases by 10, the angle of refraction is increased by one.	Warrant	
	Teacher: It is?	J. Warrant	
65	Rick: Like, er, when you subtract, the difference increases by one.	Warrant	Pupil tries to clarify
	Teacher: You mean it decreases by one.	Warrant	Teacher states the needed clarification
70	Rick: Decreases...yeh, decreases.		Pupil accepts clarification
	Teacher: All right. Yes, it is decreasing by one. Can we make a prediction from	J. Warrant	Teacher seems to accept the Warrant
75	those results? Can we predict what the angle of refraction will be for 80°? Bill.		Teacher asks if Warrant can be used in an argument to reach a Conclusion
	Bill: 43°?	Conclusion	Pupil attempts to use Warrant
80	Teacher: How did you get that?		Teacher asks for an explanation of his argument
	Bill: Er, just a guess. (Laughter)		Pupil says he did not use an argument
	Teacher: Er, what was your guess based on?	S. Warrant	
85	Bill: Er, it's going down one. Sometimes it stays the same, other times it goes down one. So, it'll be 3 for 80°.	Warrant Qualifier Conclusion	
	Teacher: So, what made you...		Teacher seems to be asking
90	what made you think it was going to go down one this time?		how the Qualifier is used
	Bill: Oh.		Pupil seems to see the weakness of his argument
	Teacher: So, in other words,		Teacher dismisses the argu-
95	you don't know.		ment
	Bill: No.		Pupil accepts dismissal
	Teacher: Well, a person by the name of Snell came along and he looked at these		*SEGMENT B-3 BEGINS* Teacher proceeds to present Snell's Warrant at length
100	angles and he came up with a law, which we now call "Snell's Law." And the way it works...well, let's first draw a diagram on the board,	Name of Warrant	The superiority over the Warrants proposed above by pupils is asserted, and the Backing the Teacher presents is not compared with the Backing used by pupils
105	and you'll see how it works.		

Commentary on the Analysis

Episode B is part of a lesson which examines angles of incidence and refraction and uses Snell's Law to introduce the term "index of refraction." This episode was preceded by the teacher's review of basic aspects of refraction phenomena and his use of an optical disc to obtain the evidence which appears at the beginning of the episode. This episode was followed by the teacher's explanation of the geometric relationship stated in Snell's Law and its use in the calculation of indices of refraction. During the episode the teacher solicits, challenges, and judges his pupils' suggestions for a Warrant which will permit the move from certain Data (lines 4-10, left column of numbers) to corresponding Conclusions (lines 4-10, right column of numbers). If established, such a Warrant could be used to predict the angle of refraction which would be observed for any angle of incidence.

Since three arguments can be identified in the episode, the analysis is done in three segments: (B-1) Susan's suggestion of a Warrant, (B-2) Rick's suggestion of a Warrant and Bill's attempt to use it, and (B-3) the teacher's indication that Snell's Law is the best available Warrant.

The teacher begins the first segment (B-1, lines 1-34) by directing the pupils' attention to the information available to them and asking if they can suggest a Warrant (lines 1-16). Susan makes a suggestion which the teacher repeats and tests against the evidence. This scrutiny seems to prompt Susan to change the wording of her Warrant (lines 30-31). In his role as critic the teacher uses the new wording as a basis for disqualifying the Warrant (lines 32-33). Susan was apparently not aware of the unacceptability of a Warrant using averages. The teacher's comment suggests traditional authority for the argument, unless he later explains why "averages aren't good enough here."

In the second segment (B-2, lines 35-96), Rick proposes a Warrant which the teacher at first seems to regard as obviously inadequate (line 42). Rick continues his presentation by describing how the evidence (Data and Conclusions, lines 4-10) seems to support his Warrant. When the teacher still seems unimpressed (lines 56-58), Rick presents his Warrant in a more general form (lines 60-63) which the teacher helps him to state clearly (lines 68-69) and which the teacher appears to accept in its clarified form (lines 72-73). As the teacher continues, he seems to indicate that judgment

should be reserved until it is learned whether this Warrant can be used successfully in a new situation. When Bill makes a prediction (line 79), the teacher's questions (lines 80 and 83-84) seem to ask how Rick's Warrant was used to make the prediction. When Bill has to amend the Warrant with a Qualifier (lines 86-87), the teacher indicates its limitation (lines 89-92) and Bill gives up his defense of the Warrant.

The third segment (B-3, lines 97-105) begins very abruptly, as the teacher announces the name of his Warrant and begins to explain it. In his subsequent presentation of Snell's Law the teacher demonstrates how the law works in geometric terms. Emphasis is on the details of the Warrant with no reference to the procedure by which the validity of the Warrant has been established. Because of its length, that presentation of Snell's Law is not analyzed here but is presented in the Appendix for the reader's examination.

The abrupt transition from the second to the third segment precludes any discussion of the difference between the arithmetical Backing of the pupils' Warrants and the geometrical Backing of Snell's Law. In the second segment, the teacher's sequence of challenges seems to imply that the step from Data to Conclusion by a Warrant must be very "tight," with no Qualifiers. It is interesting that Bill gives in (line 93) without a test of his prediction on the optical disc. This suggests that the pupils appreciate the importance of a sound and precise argument, and in this sense segment B-2 reflects rational authority. Yet from the outset (line 17) the pupils have been in a position to infer that the teacher had a Warrant ready to present if they failed to establish one. They apparently did not know that the teacher had access to Backing which was not available to them. Inasmuch as the pupils are not made explicitly aware of this situation either before or after the fact, the judgment is made that traditional authority predominages in all three segments.

Analysis of Episode C

This episode is taken from the early part of a lesson (pages 7-10 in a transcription of 30 pages) on the topic "affinity of metals for oxygen." There are twenty-one pupils in this Grade 9 class (eleven boys, ten girls), and the lesson occurs late in the school year (May 1971) during a period in the morning--10:45 until 11:25.

	TRANSCRIPTION	PATTERN ELEMENT	COMMENTS
	(A discussion of the decomposition of mercuric oxide by heat has just been completed.)		
	Teacher: So...another metal which we could use to extract from its oxide is lead, lead oxide. If you think about		*SEGMENT C-1 BEGINS*
5	it, you've only got to heat lead up a little bit and it looks quite like mercury anyway, doesn't it? Liquid lead you've probably seen--	Warrant	Teacher suggests that lead will behave as mercury did
10	it's like silver. Now. If we heat lead oxide, what would you expect, Rick? It's not as liquid as lead, it's not	S. Conclusion Data	Teacher solicits Conclusion
15	as soft as gold. What would you expect to happen if we heat lead oxide? (No response) Hm? Well what	S. Conclusion S. Conclusion	
20	could happen...what, what could possibly happen? (Some dark powder is tipped into an evaporating dish and heated over the burner.)		
	Rick: It would start it melting?	Conclusion	
25	Teacher: Well, it...yeah, it might melt if you heated it strongly. But by analogy with what happened to mercury, what might happen to	J. Conclusion Warrant S. Conclusion	Teacher judges Conclusion
30	the lead oxide?		
	Rick: Change to a gas?	Conclusion	
	Teacher: Change to a gas. It would give off oxygen, yes...give off oxygen gas.	Conclusion	Teacher adds to pupil's Conclusion as he repeats and accepts it
35	And what would be left at the bottom? (No response)	S. Conclusion	
	Lead would be left at the bottom, wouldn't it? Yeah.	Conclusion	Teacher states Conclusion and judges it correct
	Well now, in fact this	Conclusion	*SEGMENT C-2 BEGINS*
40	doesn't happen, because... why doesn't it happen?	S. Warrant	
	Janet...What am I talking about Janet (correcting himself) Nancy? Why doesn't	S. Warrant	

lead form from mer..., from lead oxide when you simply heat it by itself?	Conclusion Data	Teacher reminds pupil of other elements of the argument
Nancy: Because it, er...it has a high affinity...	Warrant	
Teacher: Because it has a... well, a higher...a higher affinity for oxygen than has mercury. All right? So, how can we get, how can we get lead--because most of the lead that's mined is found mostly as the oxide. How can we get lead from lead oxide if it doesn't release oxygen and form lead on heating?	Warrant S. Warrant Data	Teacher alters and adds to pupil's Warrant *SEGMENT C-3 BEGINS* The Conclusion is indicated, but the Data and Warrant for getting lead from lead oxide are in question
Pupil: Mix something that has a higher affinity.	Warrant	"Something" implies the need for additional Data
Teacher: Mix it with something which has a higher affinity for the oxygen which is combined with the lead. Good. And that substance would be?	Warrant J. Warrant S. Data	Teacher restates the Warrant more completely
Pupil: Um. Mercury.	Data	
Teacher: Well, you've probably seen that I've been playing around with something black which you might know is charcoal, right. Okay. (Some laughter) Now, you can...you can see that this is not apparently changing color or changing texture in any way, is it? There's no little bubbles of anything. Er, I think it should be just about hot enough. (Pause) I think it...you'd better just stand back a little bit because it sometimes pops around the place a bit. I'll take the heat away just to make it a little bit less vigorous. Now if I add some charcoal to the lead oxide...(some is added and sparks are emitted)	 Data Data	Teacher apparently ignores pupil's suggestion No argument for the specific use of charcoal is presented Teacher refers to material he began heating earlier (lines 20-22)

95	Pupil: Oh. Cool.		
	Teacher: If the, if the thing is hot enough and if the charcoal wants to combine with the oxygen more	Qualifier Warrant	Teacher presents the argument as the demonstration of the reaction proceeds
100	than the lead wants to hold onto it, then you get this fairly vigorous reaction... I'll just leave it and you'll find it'll....Can you all see	Conclusion begins	
105	what's going on? It's like a little miniature volcano, isn't it?		
	Pupils: Cool. Firecrackers...		
110	Teacher: Like bonfire night, yes.		
	Pupil: Firecrackers. Does anybody have any marshmallows. Aw, no. (Laughter)		
115	Teacher: Stand back a little bit, because it does hop around.		
	Pupils: Cool, eh. Firecracker Day (many times).		
120	Hey that is good.		
	Teacher: Now, I'll just keep it...I'll just keep it heated a little bit more and we should expect...yes, you	Conclusion completed	Teacher predicts, using Data and Warrant implied earlier
125	can in fact see...if you look over, look over the top here, you can see a little globule of liquid lead.		
	Pupils: Yeah. Yeah (many		
130	times).		
	Teacher: See that shiny... do you all see that?		*SEGMENT C-4 BEGINS*
	Pupil: Looks like mercury.	Data	Pupil reports observation
	Teacher: Looks like mercury.		
135	Right, yes.		
	Pupil: Isn't it? (Some comments, pause)	S. Conclusion	Pupil wants substance identified
	Teacher: All right. So what do you think...what do you	S. Conclusion	Teacher replies indirectly,
140	think was formed...I mean, we got to...we got to start		asking for products of the demonstrated reaction

	off, we start off with a certain number of things, we see that they react	Warrant	This Warrant is general and not specific to this reaction
145	together, and we end up with something else. Well now, we see that one of the things we end up with is lead.	Data	No argument to identify lead is provided and it is asserted that "we <u>see</u> it"
	Shirley, what would be the		
150	other stuff that we produced by that reaction? (Pause) Lead and oxygen form lead oxide, right?	S. Conclusion Data	
	Shirley: Carbon?	Conclusion	
155	Teacher: Carbon is added to it, removes the oxygen from the lead oxide. You get lead and what? Some compound containing carbon and	J. Conclusion Data S. Conclusion	Teacher rejects Conclusion that carbon is produced by stating what carbon does with respect to other elements involved
160	oxygen, what would...what would that be likely to be?		Teacher hints at Conclusion by identifying the elements that make up the compound
	Pupils: Oxide. Carbon dioxide. Carbon dioxide.	Conclusion	
	Teacher: Carbon dioxide,		
165	good. All right. So, let's put that (the evaporating dish) on one side; it's a little warm.	J. Conclusion	
	(The lesson proceeds to the decomposition of cupric oxide.)		

<u>Commentary on the Analysis</u>

Episode C is taken from a lesson in which the affinity of metals for oxygen is discussed with reference to five metallic oxides. This episode follows the introduction of the term "affinity" and a demonstration of the decomposition of mercuric oxide by heat. The teacher also has indicated that, since it was "relatively easy" to decompose mercuric oxide, mercury is said to have a low affinity for oxygen. In this episode, lead is obtained from lead oxide by heating it with charcoal (carbon)[1] so that the affinities of lead and carbon for oxygen can be compared.

[1]Carbon combines with oxygen, yet it is not a "metal" in the same sense as lead or mercury. This point did not arise in Episode C.

The episode is considered in four segments, containing the following arguments: (C-1) predicting the behavior of lead oxide when heated, (C-2) explaining the failure of the prediction, (C-3) predicting how lead can be obtained from lead oxide and testing the prediction, and (C-4) identifying the products of the reaction.

In the first segment (C-1, lines 1-38), the teacher asks his pupils to use the previously demonstrated behavior of heated mercuric oxide to predict the behavior of lead oxide when heated (lines 4-12). When there is no response, the teacher throws the argument open to the use of any Warrant (lines 17-19). That Rick's Conclusion is not the desired one is indicated by the teacher's immediate return to his instructions that the analogy with mercuric oxide be used (lines 27-30). When Rick's new Conclusion is still insufficient, the teacher amends it and answers his own further question (lines 35-38). To this point at the end of the first segment, the pupils appear to be unable to use the teacher's Warrant. The authority for the Warrant is clearly that of the teacher's position: no evidence in support of the analogy has been given, and strangely enough in the next segment the Warrant is declared false (lines 39-40).

When the second segment (C-2, lines 39-53) opens with information which forces the rejection of the "analogy-with-mercuric-oxide" Warrant, the teacher immediately (line 41) asks the pupils to supply a Warrant which would permit the Conclusion that lead oxide does not decompose when heated (even though mercuric oxide does). Nancy offers a Warrant (lines 48-49) which is presumably based upon an earlier discussion of affinity. The teacher accepts her Warrant by changing it to the comparative ("higher"); this change indicates that the Warrant is to be applied in an argument comparing the behavior of mercury and lead with respect to oxygen.[1] In this

[1]The upshot of this change is that the teacher is insisting upon the proper use of the term "affinity," which is comparative and cannot be used in an absolute sense. That Nancy did not understand this point could result from the fact that "affinity" seems to have a seductive effect, not unlike that of the term "gravity." That is, applying such a term to the relevant phenomena can generate a sense that one has explained something. In fact, a complete scientific explanation is not achieved until the Backing for Warrants which invoke "affinity" is understood. That Backing includes reference to relative strengths of bonds formed with oxygen, according to the atomic-molecular theory.

segment, as in the first, the authority for the argument is that of the teacher's position. The Warrant established in this segment rests on a Conclusion which has been stated by the teacher (lines 39-40) but which has not yet been demonstrated to the pupils.

The third segment (C-3, lines 54-132) begins with the teacher's request (lines 58-61) for a Warrant which will permit the Conclusion that lead has been separated from oxygen, given that simple heating is not sufficient. The goal of the segment thus seems to be the establishment of a Warrant. The evidence which will count for the Warrant will be the demonstration of a reaction which begins with lead oxide and ends with lead. In lines 62-63, a pupil supplies a general Warrant specifying the addition to lead oxide of a substance with "a higher affinity." The teacher accepts this Warrant by adding that the substance must have a higher affinity for oxygen than lead has. This particular pupil seems to understand the theoretical Backing which the concept of affinity provides for this general argument. This passage (lines 53-68) seems to suggest rational authority, perhaps because all information is conditional and evidence is not required.

When the teacher asks for specific information (lines 68-69), he ignores the suggestion about mercury, which perhaps indicates that he expected pupils to reply not by completing an argument but by recognizing the substance (charcoal) he has at hand. The teacher's statements at this point (lines 71-84) show that lead oxide is being heated as the discussion continues; in fact, he began heating it in segment C-1 (lines 20-22). Although not explicitly identified as such, his report in lines 76-82 seems to refer back to segments C-1 and C-2, during which it was a matter of debate whether lead oxide would or would not decompose by heating alone. The teacher has asserted the Conclusion that it would not (lines 39-40), and this descriptive report is the evidence in support of that Conclusion.

The central point of the entire episode is discussed in lines 96-132. As the reaction of carbon with hot lead oxide proceeds, the teacher notes a Qualifier (lines 96-97) that the heat is necessary (though not sufficient), and then states conditionally the specific Warrant that charcoal combines more strongly with oxygen than lead does (lines 97-101). The teacher indicates that this Warrant permits the Conclusion that a reaction will occur (lines 101-102) in which lead will be one of the products (lines 125-128).

Segment C-3 seems to contain all the necessary elements for establishing on rational authority the Warrant that carbon has a higher affinity for oxygen than lead has. However, the episode in toto lacks information for judging the teacher's provision of Backing for the chemical concept "affinity."

The remainder of the episode is taken as a fourth segment (C-4, lines 133-168) because the teacher directs the subsequent discussion away from the identification of lead, appropriate to the third segment, toward the identification of the other product of the reaction. If the Warrant (lines 97-101) in segment C-3 is to be established on rational authority, the pupils require a rational basis for identifying the shiny product as lead. This matter is placed in doubt when a pupil asks (line 136) whether the product is mercury. In response the teacher states a general Warrant (lines 142-146) about reactants and products in any chemical reaction and then asserts that one of the products is lead (lines 146-148). When the teacher asks for a Conclusion (lines 149-151) using the general Warrant to identify the other product of the reaction, he has effectively transformed the earlier request for independent identification of lead into a request for identification by argument of the other product. Shirley's suggestion that it is carbon (line 154) is countered by the teacher's account of the role of carbon (lines 155-157) in the reaction. Unfortunately, his account assumes the very Warrant (lines 97-101) for which independent identification of lead is required (if pupils are to accept the Warrant on rational authority).

The effect of segment C-4 is to convert the apparent rational authority for the Warrant in segment C-3 to the traditional authority of the teacher's position. A pupil has challenged the identification of lead as a product, and in response the teacher has simply asserted that the product is lead. One alternative might have been to describe a separate test for the element lead, within the context of chemical theory.

Segment C-4 itself is a Warrant-using argument, and the Backing for the teacher's very general Warrant about chemical reactions (lines 142-146) was probably established earlier in the year. When the pupils are not able to use the Warrant as desired, the teacher answers his own question by giving the elements and asking for the name of the compound (lines 158-161). The Conclusion is now rather obvious, and the pupils' answer is accepted (line 165). But the argument in segment C-4 depends upon the identifica-

tion of lead, just as did the argument in segment C-3. Since the identification of lead is made on the authority of the teacher's position, the judgment is made that the arguments in both segments suggest traditional authority.

CHAPTER III

REFLECTIONS ON THE ANALYSIS

The concepts of authority in teaching and of elements in an argument, as developed in Chapter I, have been used in Chapter II to guide the analysis of three science teaching episodes. In this final chapter a somewhat broader view is taken of the episodes analyzed, in order to reflect back upon the concepts of authority and argument and to make note of some interesting and distinctive features of each episode. In addition, some commentary is in order about the potential of this approach to examining science teaching.

Episode A: Warrant-Using Becomes "Warrant-Stating"

Although the initial statement of Data and Conclusion suggests that a Warrant is to be established, this episode as a whole seems instead to illustrate Warrant-using, and the teacher's goal seems to be to have someone make a correct statement of each Warrant being used. Apparently the episode is a review of previous discussions of static electricity as a prelude to introducing the study of current electricity. Inasmuch as the Conclusions that electrons have moved from one material to another cannot be checked by direct observations, the arguments in this episode rely heavily for Backing on the model of an atom in which outer electrons are thought to be somewhat free to move, under certain circumstances.

Why the teacher's insistence on correct statements of Warrants? Possibly because it is a review lesson. But consider another possibility, emerging from the analysis as an interesting and probably somewhat common feature of science teaching which involves such conceptual devices as an "Electrostatic Series." In this particular case, pupils can move from Data to Conclusion by one of two routes: either they formulate and use a Warrant, or they simply make use of the order of materials in the series (as listed on the blackboard). When a pupil states a correct Conclusion, the teacher could be investigating

which route was taken by asking for a statement of the Warrant, if he also sought further evidence that it has been used correctly.

However, this teacher seems to assume pupils have used a Warrant in each case, and to overlook the possibility that they could be taking the alternative route of simply noting the order of materials in the series. This interpretation is based on two important features of the episode. First, the teacher insists that some reference be made to "stronger attraction for electrons," a significant part of the Backing one would use in formulating a Warrant in this case. Second, the pupils continually speak of materials "holding" electrons. Their use of the word written with the series on the blackboard is strong indication that they are using the series to reach Conclusions without formulating Warrants.

In the end, the teacher settles for statements of Warrants, stopping short of evidence that pupils have used them. Accordingly, the judgment is made that Warrant-using arguments have degenerated into "Warrant-stating" mock-arguments.[1] A potentially useful hypothesis, in such a situation, is that pupil inability to state Warrants could indicate that Warrants are not being used at all.

Analysis of Episode A in terms of Toulmin's argument-pattern has some promising possibilities, then. One can identify the shift from Warrant-using to "Warrant-stating," and thereby contemplate modifications which might improve the communication between teacher and pupils. Further, one can recognize that, in the confusion over the immediate task of "Warrant-stating," little attention is paid to bringing Data, Warrant, and Backing together in proper relationship so that Conclusions could be reached on the basis of rational authority.

Episode B: Warrant-Establishing Becomes "Warrant-Asserting"

Episode B is a rather straightforward instance of a situation in which a Warrant needs to be established. Pupils observe the collecting of evidence (tabulated as Data and Conclusions) for which a Warrant is to be established. They are asked if they can see a relationship, or Warrant, by which each

[1] "Warrant-stating" is not one of Toulmin's terms, but has been coined here because it captures and describes the essence of what seems to be happening.

Datum can be converted to its corresponding Conclusion. When their attempts are unsuccessful, the teacher presents Snell's Law as the Warrant which fits the regularities observed in the refraction of light.

It is important to note that the pupils' two unsuccessful suggestions explore the possibility of an arithmetical relationship. Subsequent to the episode (refer to the Appendix), the teacher presents a description of the geometrical relationship which is attributed to Snell. The pupils' suggested Warrants rely on a different Backing than does the Warrant presented as Snell's Law. Apparently the pupils were not familiar with this kind of relationship between measured angles; that is, they were not acquainted with the Backing necessary to suggest a Warrant based on a geometrical relationship. It thus appears that the teacher asked the pupils for a relationship which they could not have been expected to "see" by looking at the evidence.

Analysis of Episode B points up an important general feature of science teaching in which laws and theories (in general, Warrants) are being presented to pupils for the first time. Once a Warrant has become familiar and can be used easily, its Backing is virtually taken for granted. However, in the initial establishment of a law or theory, it is essential that the Backing for the Warrant be demonstrated, if each pupil is to be enabled to regard the Warrant as established on rational authority.

This episode has been judged to suggest traditional authority because no explicit reference is made to the function and import of geometrical analysis as Backing for the Warrant which needs to be established. The teacher's initial request for a Warrant from the pupils could be a very successful motivational technique, but only if it is carried through. In the sequel to Episode B which appears in the Appendix, the teacher's explication of Snell's Law stresses the use of the law as a Warrant and fails to call attention to the crucial difference between Snell's approach to finding a relationship and that used by the pupils. By asking the pupils to accept and use the Warrant on his authority alone, the teacher is in effect asserting Snell's Law as an acceptable Warrant.[1] Ultimately, this analysis reminds one that there is more to a law or theory than its use as a predictive device, and

[1]"Warrant-asserting," like "Warrant-stating," is not one of Toulmin's terms, but has been coined because of its usefulness in this kind of analysis.

that the "something more" of its Backing is quite appropriately considered when the law or theory is first presented to pupils.

Episode C: Warrant-Establishing Becomes Circular

In the opening segments of Episode C, the teacher displays skill in using an interesting technique for setting up a problem which requires establishment of a Warrant. Pupils are asked to use an analogy based on earlier discussion, and then they are told that the analogy fails. The teacher's subsequent demonstration seems to complete an argument to establish the required Warrant. Only his treatment of a question about the identity of a product of the reaction forces the judgment that traditional authority predominates in the episode as a whole.

Analysis of Episode C calls attention to the general relationship between the observations made in a demonstration or experiment and the Warrant-establishing argument for which they are to serve as evidence. In this study the position has been taken that rational authority is suggested by science teaching if all elements of the argument are present in correct relationship. Failure to achieve this goal demands a judgment that traditional authority predominates, and such failure can occur in many ways.

Episode C illustrates a failure to keep the evidence provided by the demonstration independent of the argument being made. Instead of considering directly how one product of the reaction can be identified as lead, and not mercury, the teacher leads the students through another argument. This strategy of posing a question is quite effective earlier in the lesson, but the teacher seems unaware that his new argument assumes the challenged identification of lead as a product of the reaction. The result is that the argument becomes circular. Thus one is reminded that effective use of a particular teaching strategy requires continuing consideration of its impact on the logic of the argument being developed.

In Conclusion

Just as one cannot observe without some idea of what to look for, so one cannot reflect upon teaching practice without analytic techniques suited to one's particular purposes. This study was motivated by the investigator's desire to explore systematically some initial reactions to observing these

and other episodes of science teaching, and to reflect on his own teaching practice as well. The analysis in Chapter II and the reflections in this final chapter are, of course, a result of deciding to look at science teaching through the eyes of selected analytic distinctions.

The analyses of argument and authority presented in this study are clearly not exhaustive. Yet they do seem powerful enough to permit one to draw inferences about the use of argument and authority in science teaching. It is hoped that the study will enable others who are interested in these aspects of teaching to analyze in similar terms the teaching they conduct or observe. Such conceptual analysis can help one to identify potentially appropriate modifications of teaching practice. Without analysis, one would come upon those modifications only accidentally, if at all, and would lack a basis for defending them.

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APPENDIX

The complete but unanalyzed transcription of that portion of the lesson which follows Episode B is provided here in support of the assessment about authority reported in the Analysis of Episode B above, pages 24-28.

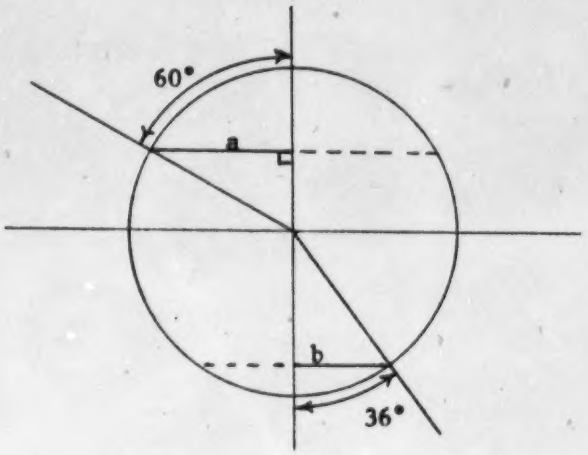
Teacher: Well, a person by the name of Snell came along, and he looked at these angles and he came up with a law, which we now call "Snell's Law." And the way it works...well, let's first draw a diagram on the board, and you'll see how it works. We'll take observation number six--that is, the angle of incidence of 60° and the angle of refraction is 36°--and we'll draw a diagram. What must we put in this diagram? Barbara.

Barbara: The normal.

Teacher: Now, since we're going to do this accurately, I have a little device here which measures angles. Does anyone know what it's called? Nancy.

Nancy: Protractor.

Teacher: That's right. (During the following discussion, an accurate diagram is drawn on the board.)



Okay, so I'm going to measure an angle of incidence of 60°...I'm going to read this angle off because I want to draw it accurately now.... Now, we'll draw the angle of refraction equal to 36°. (Pause) Now, Snell drew similar diagrams for every one of...every one of his observations. Now he mathematically found a relationship between the angle of incidence and the angle of refraction. We are not going to go through the mathematics because it's going to get very complex and it's too hard for us at this time. However, what I will do is I will tell you the essence of what his mathematical, er, predictions were. Here we have a...I'll put this up. (Pause, laughter)

Pupil: Compass.

Teacher: He took a compass and he said, "Let us draw a circle with the center at this point where the incident ray meets the...er, surface..." (Pause) If we draw this circle, we then take the point at which the incident ray strikes the circle and draw a line from this point on the incident ray to the normal at an angle of 90°. Let's use a different color chalk here. We'll do the same thing for the refracted or emergent ray--where it strikes the circle, we will draw a line from where the ray strikes the

circle through the normal at an angle of 90°. (Semi-chords "a" and "b" are drawn.) To help us identify this line, if we continue drawing this straight across the circle--which we are not going to do--but if we did, what would we call the line which cuts a circle? What do we call any line which cuts a circle? Monica.

Monica: A chord?

Teacher: Yes. So what will we call the line which cuts the circle, um... what will we call half of that line which cuts the circle? Monica.

Monica: Semi-chord?

Teacher: So, we'll call this one ("a") the semi-chord in the first medium, and this line here ("b") the semi-chord in the second medium. Well, Snell found that if we measure the length of the semi-chord in the first medium and we measure the length of the chord in the second medium and we divide one into the other, we will always get a constant number. (He writes, "ratio of semi-chord in first medium to the semi-chord in second medium equals a constant.") Well, let's do this...(measuring)...um, 19.5 centimeters...and 13.2 centimeters. (He writes "19.5 cms./13.2 cms.") What happens to the units here when we divide one into the other? Rick.

Rick: They're cancelled out?

Teacher (cancelling the units): So we end up with a ratio and this ratio's simply a number. Now, work this number out in your notebooks. I'll take the easy method. (He uses a slide rule; pause.) Who has it? (Pause; he writes "=1.475.") All right. Who has it? (Pause) What, are you waiting for me? That's wrong, I guarantee it. (Pause) Monica.

Monica: I got 1.5, um, 32. It could be a little less.

Teacher: Anybody else get that--1.53? Check your math, Monica. Clark.

Clark: 1.5?

Teacher: Check your math. Barbara.

Barbara: I got 1.473.

Teacher: Well, that's much closer. Okay, let's leave it at 1.47 or 1.48 rather. (He changes the number on the board to "1.48.") We'll round it off. Now, according to Snell's Law, the ratio of the semi-chord in the first medium to the semi-chord in the second medium is always a constant. Well, if that's true, then if we take our observation number four here--having our angle of incidence at 40° and our angle of refraction at 26°--and we do the same thing over again, we should get the same number--1.48... or within experimental error, very close to that number. Well, let's do it. (The drawing of an accurate diagram is repeated for this pair of angles.) We will take...our compass and place the center at a point where the ray of light strikes the surface...what radius will we take? Simon.

Simon: It doesn't matter.

Teacher: Speak up, Simon.

Simon: It doesn't matter.

Teacher: That's right. Okay. So we choose any radius. Now, of course the larger the radius, the better. Why? Bill.

Bill: You get, er, because it will be more accurate.

Teacher: Why will it be more accurate?

Bill: Because it will be...so that it'll be large...like...I don't know.

Teacher: Well, you have the right answer.

Bill: Because it will be more accurate, because, um...

Teacher: Because?

Bill: Because, er, you get more units in?

Teacher: All right. Who can help him out? Monica.

Monica: Um, well, when you get more units it's easier to measure.

Teacher: Why will it be easier to measure?

Monica: Because it's going to have bigger numbers.

Teacher: Right. Larger numbers are more accurate to measure than smaller numbers. All right, let's do the same thing again. We'll take the ratio of the chord in the first medium...of the semi-chord in the first medium divided by the ratio, or divided by the chord in the second medium...the semi-chord in the second medium, rather. And we'll see if it works out to the same number. (Pause) By the way, this is for observation six and now we're going to do it for observation four (labelling the first ratio and the space for the second ratio). All right, just so you people don't think I'm cheating, Doug, measure it in centimeters...or Bill, rather. Measure it in centimeters, Bill. (Bill moves to the board and measures the semi-chords.) As close as you can, Bill.

Bill: Um, the angle of incidence is...

Teacher: Not the angle of incidence.

Bill: Or the, er, length is 9 centimeters.

Teacher: What is it?

Bill: 9 centimeters.

Teacher: No, Bill. It's more than that (some laughter).

Bill: It's still 9. Oh no...I don't have.... It's, er, 19.

Teacher: Okay, write it down. (Pause)

Bill: 12.8.

Teacher: Okay. (Bill returns to his seat. The ratio on the board reads, "19.0/12.8.") Okay, so the length of the semi-chord in the first medium is 19.0 centimeters. The length of the semi-chord in the second medium is 12.8. Let us divide these out and see if we come up with the same number. And if Snell's Law is...is correct, we should come up with the same number. So do that. (Pause. The fire alarm sounds and everyone leaves the room.) Okay. Out this door. (The lesson resumes. The teacher writes

as pupils return, "Homework: repeat the calculations for the other observations and see if the ratio is still = 1.48.") All right. Very quickly--since we only have about thirty seconds or so. If we divide 12.8 into 19.0 we get the same number approximately (writing "=1.482"). Now, it's not exact. Who can account for the fact that it's not exact? Barbara.

Barbara: You could have measured it not quite exactly.

Teacher: That's right. It's not precisely accurate. Now for homework what I want you to do is repeat, er, the method of calculating this constant using, er, the circle method and the ratio of the semi-chord, and determine whether or not the rest of the observations also get approximately the same number. And if they do, we will believe Snell's Law. And tomorrow we'll write Snell's Law on the board.

(The lesson ends.)